Two proposals for unlimited fresh water

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Abstract: The world water crisis may be more serious than generally appreciated. One reason for this is that the main response has been to increase storage of rain rather than to increase the amount of fresh water. Another is that fossil groundwater has been widely seen as inexhaustible. Two fresh water collecting systems are outlined here and it is argued that they have no ultimate limitation, either by the availability of water or by environmental constraints. The first system is the Water Road, with a large surface area so allowing distillation by solar and wind energy. The other is a refrigerated wind turbine system, Water from Air, which offers novel means to collect water from wind.

Keywords: arid drought; seawater distillation; seawater inland; solar distillation; water condensation; water desalination; water ecosystem; water from air; wind condensation; wind turbine refrigeration.

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Biographical note: Dr. M. Whisson is a Director of Water UN Limited and Needlesleeve Pty Ltd, two companies in Perth, Western Australia, established to develop some of his numerous inventions. A graduate in medicine from the University of Melbourne, after experience in a wide range of clinical medicine, he spent many years in cancer research at The Institute of Cancer research, London, and other leading centres, then returned to Australia as Haematologist and Deputy Director of the Red Cross Blood Transfusion Service, later devoting his time to the development of medical and related inventions.

1 Introduction

It is anomalous that, with our mastery of science and technology, we, as a species, remain millions of years behind the Namibian desert beetle Stenocara in still being dependent for survival on the capricious fall of rain (see, for example, Cloudsley-Thompson, 2001; Parker and Lawrence, 2001). Even viewed from the perspective of the evolution of life on Earth, the water crisis is a major event but our response to this threat up to now has been largely inappropriate. Rather than attempting to increase the amount of fresh water, we continue to engineer redistribution by the destructive exploitation of surface accumulations (Reisner, 1993; Quing, 1998; Keller, Sakthivadivel and Seckler, 2000). Where this fails to meet requirements, fossil water is accessed by deeper and deeper bores, already resulting in subsidence of ground level (Agnew and Anderson, 1992; Pearce, 2004; Endersbee, 2005). There is a persistent belief that groundwater is significantly recharged by surface water, but Endersbee (2005) argues very convincingly that groundwater is of ancient origin and not significantly replaced. Where communities have become dependent upon groundwater the sudden exhaustion of that source will be catastrophic and this reinforces the impression that the severity and rate of development of the world water crisis is seriously underestimated. As discussed in Kobori and Glanz (1998) and by Quing (1998) the response to date has been of a short-term and ecologically unsustainable kind. As pointed out in Ohlsson (1991), lack of water is already a frequent cause of conflict. It is clear that there is now a need for access to potentially unlimited supplies of water and, bearing in mind current pollution, global warming and the developing shortage of fossil fuels, that water must be obtained using renewable sources of energy.

There are two, and only two, unlimited sources of water: the sea and the air. The volume of water on Earth is estimated to be 1.26×10^{21} l, 98% of which is seawater, with a surface area of 2.9×10^7 km^2. The surface, acted on by solar radiation, turbulence and wind, liberates water into the atmosphere. The bottom 1 km of air, with a volume of 5×10^7 km^3, is estimated to contain about 1×10^{15} kg of water with a half life of a few days. Harvesting of water from the air on a very small but socially important scale has a long history and desalination of seawater by reverse osmosis and flash distillation is now receiving attention but, in the context of world needs, pollution, the Greenhouse Effect, and the developing fossil fuel crisis, the development of these systems can offer no more than a short delay in the onset of global life-threatening water scarcity (Ohlsson, 1991; Agnew and Anderson, 1992).

It is my intention here to suggest that it is feasible to obtain unlimited supplies of fresh water in an ecologically sustainable way. A large-scale solar-powered macro-engineering project can provide unlimited quantities of fresh water from the sea and a complementary community-based development of large numbers of wind-powered condensation units can provide unlimited supplies of fresh water from the air.

2 The Water Road

This is essentially a desalination system aimed at avoiding the high fossil fuel requirements and potential toxicity of Reverse Osmosis, and distillation systems based on boiling such as Flash Distillation as discussed by Agnew and Anderson (1992) and Garcia-Rodriguez, Romero-Ternero and Gomez-Camacho (2001). Many solar and wind-assisted systems have been constructed (Loupassis, 2002). Most of them have been quite small and almost all incorporated electricity generation and storage as an intermediate form of energy, with an associated loss of efficiency and increase in complexity. A key reason for this design philosophy has been that desalination plants have been built on the model of an industry, concentrated in high technology premises of small area rather than as community-based ecological systems distributed over a wide geographic area. A further reason is that existing systems are difficult to operate reliably and efficiently when powered by variable energy sources such as solar and wind. There have been attempts to build small-scale solar stills in the past, some showing moderate success, but almost all incorporating a closed greenhouse effect vapour collection chamber. The effect of this arrangement is that the air above the solar heated water rapidly becomes saturated so that evaporation rate becomes equilibrated with condensation rate early in the day, with no further water production, the total daily output usually being only about

3 l m^{-2} day^{-1}. What is proposed here is to use low technology but ingenuity and large-scale macro-engineering to achieve evaporation from seawater by the direct action of solar and wind energy on seawater. Clearly, to achieve this, a very large absorption and evaporation surface is required to make use of the low energy density of surface solar irradiation, amounting to not more than 40,000 kJ m^{-2} day^{-1} even in hot arid areas. For this reason, the proposal is to arrange for distillation to occur during the transfer of seawater inland to the area of need. This seems counter-intuitive, but immediately provides a high surface area. A slow flow rate through a wide pipeline under transparent heat-insulating cover is used, and if greater capture of solar energy is required a simple reflective fence such as polished aluminium sheet can be erected on one side of the solar-absorbing pipeline. In this way, a large surface area of water is exposed to the sun over several days, and the large surface makes use of wind turbulence on the seawater surface as in the natural process of transfer of surface water to the air over the open sea. This system of evaporation also avoids the inhibitory effect of water vapour saturation of the evaporating air.

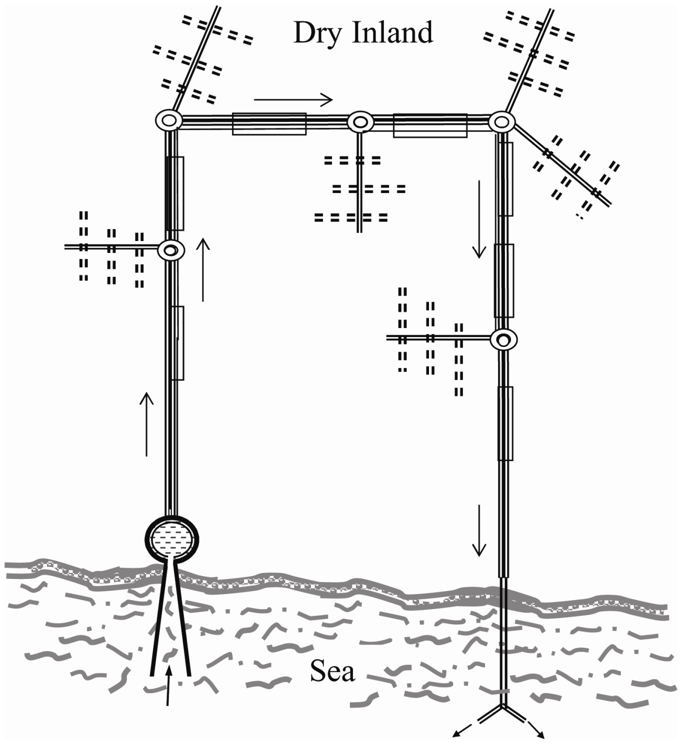
Clearly, it is essential to discard the concentrated seawater safely. The answer is to return it to the sea, preferably with further distillation occurring on the return journey. The concentrate should be sterile, near ambient temperature, free of additives and, to avoid incrustation in the system, have a salt concentration less than 15%. One attractive option is to divert some of the concentrate to a mineral processing plant where there should be large economic advantages in comparison with traditional solar ponds which discard large quantities of distilled water as a waste product. A small fraction of the brine concentrate might also be directed to a pond with transparent cover. Such systems have been shown to provide very efficient collection of solar energy as heat, the hot salt concentrate remaining at the bottom of the pond below less concentrated brine, which in this case could be seawater acting as a greenhouse radiation trap. The high temperature might then be used to drive heat engines. Such an arrangement could be adapted to supplement the solar and wind power required by the Water Road.

Perhaps, the main challenge in this kind of system is to achieve condensation of the water vapour obtained from the seawater surface. Here, this system has two advantages. By evaporating at moderately elevated temperature simply arranging for the vapour to lose heat to the incoming wind will cause most of the water vapour to condense. This is a consequence of the steepness of the temperature/water vapour pressure curve above 50 °C. The formation of a cloud of micro-droplets is of course insufficient to recover that water. There must be coalescence of the ‘fog’ droplets. Here, there is an advantage in achieving evaporation by allowing wind to blow at high velocity over the warm seawater surface. This will carry a small amount of salt into the air and sodium chloride crystals are very efficient nuclei for the formation of water drops. Even so, refrigeration is desirable and this is discussed below in the Water from Air proposal.

The Water Road can be constructed in many alternative patterns to suit local topology and it is particularly recommended that some of the seawater distillation pipeline should be on an elevated platform which allows farmland, housing and desirable ecosystems to flourish in irrigated shade below.

One layout pattern is diagrammatically shown in Figure 1. The first point to note is that intake of seawater into the system may be assisted by siting the intake at the apex of tapered walls or a tidal estuary. In this way, the momentum of wave action and tidal momentum can direct seawater into an elevated reservoir. The function of this reservoir is not only to store seawater, but also to absorb solar energy to achieve an initial small rise in temperature. Therefore, it should be of large surface area, shallow, and be covered by a transparent roof. With a depth of 1 m, mixed by turbulence, a mean irradiation of 30,000 kJ m^{-2} day^{-1} should increase the temperature by around 5 °C day^{-1}, so that an average holding time of four days will allow seawater with an ambient temperature of 20 °C to enter the Water Road at 40 °C.

Figure 1 Diagrammatic representation of the main principles of the Water Road

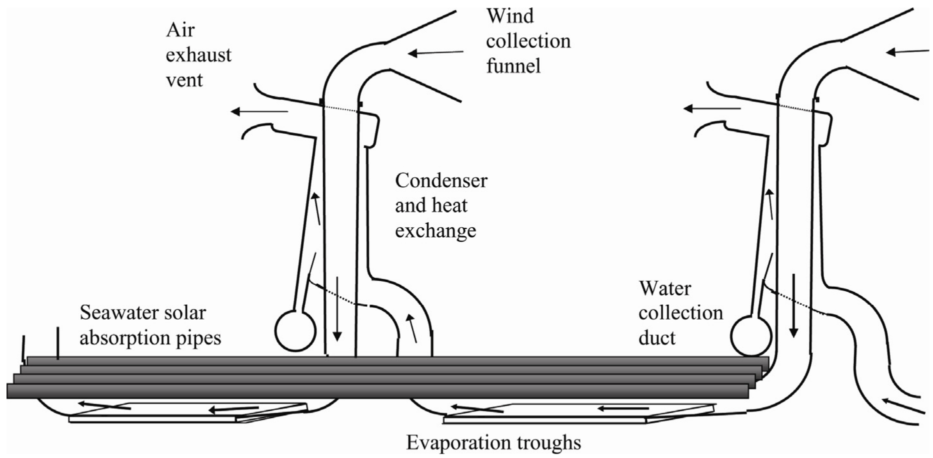


Note: Seawater is accumulated in a shallow coastal reservoir with the aid of tidal and wave power and moved inland to arid areas through solar absorbing channels. Hot seawater is run into evaporation troughs below and distilled with the aid of wind and the distilled water piped to areas of need. Concentrated seawater is returned to the sea.

The Water Road concept does not aim to achieve evaporation by boiling, but a high vapour pressure is required at the water surface. A working temperature of 70°C or higher is required by the system to provide a working vapour pressure of 30 kPa. With a 10 m wide pipeline 0.5 m deep under a polycarbonate or other suitable transparent roof and a flow rate of perhaps 200 m $hour^{-1}$, a working temperature of 75°C should be achievable in four days, or about 20 km flow.

Starting at about this distance from the coastal intake, then, evaporation troughs are placed beneath the absorption pipe. These are shown at intervals in Figure 1 and a perspective view is shown in Figure 3.

Figure 2 Preferred arrangement of the Water Road showing a wide array of small-diameter black pipes for solar heating of seawater, with wind blowing over shallow evaporation troughs ducted through condenser ducts cooled by incoming wind

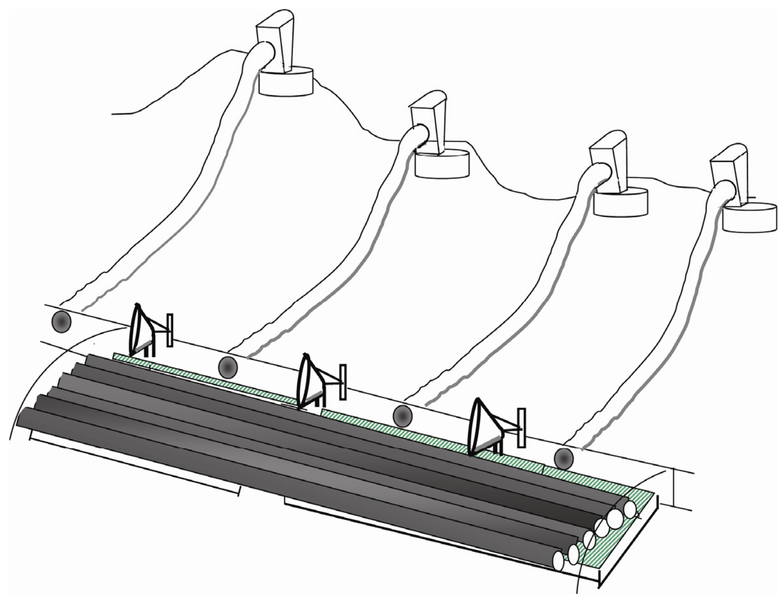


One of the choices to be made in devising a system of this kind is whether to separate the solar absorption step from evaporation with associated loss of heat of vaporisation. There are several advantages in separation of the two processes, the main one being that raising the temperature in solar absorbing pipes without undue scaling is easier to arrange in filled pipes, with a minimum of evaporation. Separation of the evaporation step also allows accelerated evaporation by high velocity wind. The cooling and removal of seawater concentrate for return to the sea is also simplified and the difficult step of condensation can more easily be optimised. Referring to Figure 2, hot seawater is dribbled at controlled intervals into the evaporation trough below. Wind captured by funnel passes beneath the hot absorption pipes over the evaporation trough then is ducted up to a condensation chamber. In Figure 2, the wind is shown in a duct passing through the water vapour-laden air as it is ducted up through the condensation chamber. Some of the heat of condensation is thus transferred to the incoming wind and helps to increase the rate of evaporation.

There is a considerable literature on the calculation of evaporation rate by wind passing over water, but the subject remains largely empirical. An early discussion by Warren Smith (1909) remains useful to this day. A more detailed analysis is presented by Singh and Xu (1997). In this instance, it may be possible to concentrate wind to quite high velocities and evaporation under a closed hot roof of seawater pipes might require special analysis. It may suffice here to apply the original Dalton relationship, $E = f(u)(e_w – e_a)$, where E is the evaporation rate, u is wind velocity, e_w is the saturation vapour pressure at the water surface and e_a is the vapour pressure in the wind. In SI units, at a wind speed over the evaporation trough of 5 ms^{-1}, water temperature of 65°C, saturation vapour pressure e_w of 160 hPa and wind vapour pressure of 20 hPa. The estimated evaporation rate is 2.24 m month^{-1}. With an evaporation trough area of 5000 $\text{m}^2\ \text{km}^{-1}$ of absorption pipeline the volume evaporated would be 11,200 kl $\text{km}^{-1}\ \text{month}^{-1}$, or 13 gl/100 km y^{-1}.

An alternative arrangement of the Water Road is shown in Figure 3. Here, advantage is taken of the lower density of humid air. Air emerging from the evaporation troughs is ducted, preferably through light plastic ducts, to condensation chambers placed on hills. The wet air, which is of lower density than the dryer ambient air, will rise by convection, aided by the wind blowing over the evaporation troughs. It is difficult to arrange conservation of the heat of condensation with this arrangement but there is the considerable advantage that the fresh water is produced at an elevated site and can then be distributed to areas of need by gravity flow.

Figure 3 Alternative arrangement of the Water Road taking advantage of the lower density of wet air



Note: Condensation chambers are sited on convenient hill-tops with the advantage that fresh water can be distributed by gravity without the need for pumping.

The water in the evaporation troughs, which are shallow and intermittently topped up, loses a great deal of heat of vaporisation. This water is directed to pipes generally parallel to the incoming seawater pipes and running back to the sea. It is desirable to keep salt concentration below 15% to reduce salt encrustation. Conductivity monitoring may be desirable to trigger drainage of the troughs. Pumping of this reduced volume of water will be required and it is envisaged that wind turbines would be placed at intervals for this purpose. These could drive helical pumps without the need for the intermediate generation of electricity. A perhaps trivial point to note is that the same turbines could assist the flow of the seawater inland where necessary and in this case frictional loss does not represent a loss of efficiency because it would add to the temperature of the seawater.

The output of the system can be estimated in different ways. The main factor is the available solar radiation, but the wind plays an important part in both evaporation and condensation.

A practical construction for most arid areas might be several Water Roads of 1000 km, each giving an output of 130 gl y^{-1}, rain or no rain, drought or no drought, arid desert or tropical farmland, oil or no oil, coal or no coal, with no destruction of lakes or rivers.

3 Water from air

Consideration of the technical problems of achieving condensation in the Water Road and recognition of the vast and unlimited quantity of water in the ambient air led to the development of the Water from Air proposal. The recovery of water from the ambient air, on a large scale and without the use of fossil fuels, is more challenging than the recovery of fresh water from heated seawater. The main reason for this is the relatively flat relationship between vapour pressure and temperature at common ambient temperatures. At a relative humidity of 60%, dropping from an ambient air temperature of 20° to 5°C can only recover some 10 g water per cubic meter of air. The problem appears less daunting, however, when it is recognised that air is easily accessed and that a very large volume is available. A 10 m^2 aperture, for example 2 m × 5 m, facing into a moderate breeze of 10 kph will acquire 100,000 m^3 of air containing 1,000 kg water per hour. An efficiency of only 20% would provide a very acceptable and useful system, especially recognising that thousands of such systems could be installed in all areas where water is required. The wind blowing into the condensation system does not provide sufficient power to refrigerate all of that wind but the answer is straightforward. Additional turbines coupled to the main refrigerated turbines are placed so that they capture energy from the wind bypassing the condensation duct.

The system is under advanced development in Perth by Water UN limited and one version is illustrated in Figure 4. The main challenges are, firstly, the development of an environmentally acceptable wind turbine suitable for collecting energy from wind entering a condensation duct. Secondly, because condensation of water from the air needs time and exposure to a large cold surface, the wind turbine preferably provides initial cooling of the air passing through it. Finally, to achieve rapid coalescence of condensing water drops without adherence to cold surfaces a satisfactory system requires the refrigeration of special water-repellent surfaces. All of these requirements are being met by the Water UN limited development programme in Perth, Western Australia.

The main innovation is a new type of wind turbine on which patents are pending. This is quiet, with a high efficiency. As can be seen in Figure 4, the turbine has multiple rotating components and the axes, which may be vertical or horizontal, are transverse to the wind. A large condenser chamber is behind the turbine and shaped so that the turbine bank in front of the intake aperture faces into the wind. The new turbine has an integral refrigeration system to drop the temperature below dew point so that wind passing through the turbine undergoes initial chilling. Excess power, partly derived from turbines outside the airstream entering the condenser chamber, is coupled to a conventional refrigeration system which drops the temperature of plates in a downwind condensation duct to close to 0°C. Most importantly, the cooled surfaces have a Stenocara or Lotus leaf-like surface. There have been important developments in this area in recent years, for example, Parker and Lawrence (2001), Wagner et al (2003), Cheng and Rodak (2005), Wu, Zheng and Wu (2005), Lin and Shou (2006) and Zhang et al (2006). Natural non-wettable surfaces have a microscopic pattern of hydrophilic ridges and hydrophobic grooves which allow water droplets to coalesce and drain from the surface even when just a few degrees from horizontal. In Western Australia, we have plates coated with such a surface which when refrigerated allows the rapid condensation of water as droplets which rapidly drain from the surface allowing collection. There is one further requirement for rapid condensation. The process is accelerated by nuclei in the air around which condensing water may accumulate. Air processed in coastal regions contains traces of salt water. On cooling, sodium chloride separates and forms microscopic condensation nuclei. In inland regions, it may be necessary to spray traces of brine into the air intake turbine.

Figure 4 Perspective view of one version of the Water from the Air system

Note: Refrigerated turbines of new type, assisted by non-refrigerated power turbines, cool the wind entering a condensation chamber where further refrigeration and condensation occur before exiting from a wind-vane shaped exhaust vent. Condensed water drains to a tank below the system.

In summary, two systems are proposed to provide fresh water using methods unlimited in the long-term by the availability of energy or of water and ultimately making it possible to restore the natural flow of rivers and the restoration of ecosystems and environments now largely destroyed by dams, by the exploitation of lakes and by the increasing withdrawal of water from aquifers. The two systems are seen as complementary, the Water Road providing water to large arid geographic areas and the Water From Air units providing dispersed multiple water collection from the air wherever it is needed, whether on high industrial buildings, farm buildings, coastal cliff-tops, remote sand hills or small isolated communities.

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